*Spectrum 2002 Conference*

*August 4-8, Reno, NV*

# Risk-Based Performance Assessments for Long-Term Cover Systems: Sensitivity and Uncertainty Analyses

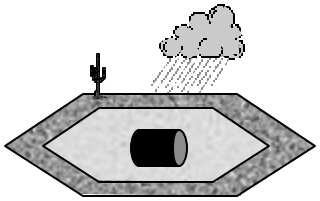
**Clifford K. Ho, Bill W. Arnold, John R. Cochran, and Randal Y. Taira***

*Sandia National Laboratories*
*Albuquerque, New Mexico*
*(505) 844-2384*
*ckho@sandia.gov*

**Pacific Northwest National Laboratory*


Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

# Overview



- **Introduction**
- **Approach**
- **Demonstration**
- **Impact and Summary**

# Introduction

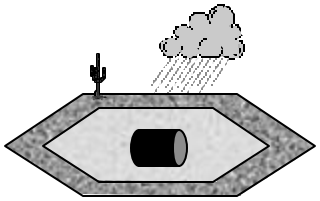
- **Engineered covers are needed to assist on-site isolation of subsurface contaminants in landfills, waste tanks, and other disposal sites**
- **Seven DOE Operations Offices have indicated major needs for long-term cover systems**
  - **Albuquerque, Idaho, Nevada, Ohio, Rocky Flats, Richland, and Savannah River**
- **DOE 2006 Accelerated Cleanup Plan identifies use of surface barrier systems as a vital remedial option**

# Problem Statement

- **Need rigorous method to evaluate long-term performance of covers with quantification of risk and uncertainty**
- **Need way to identify parameters and processes for performance verification and monitoring**
- **Need more rigorous methods to compare alternative designs and approaches**
  - **Reduce Costs**
  - **Meet regulatory performance metrics and schedules**

⇨ **Develop risk-based performance-assessment approach for selection, design, modeling, and monitoring of long-term covers**

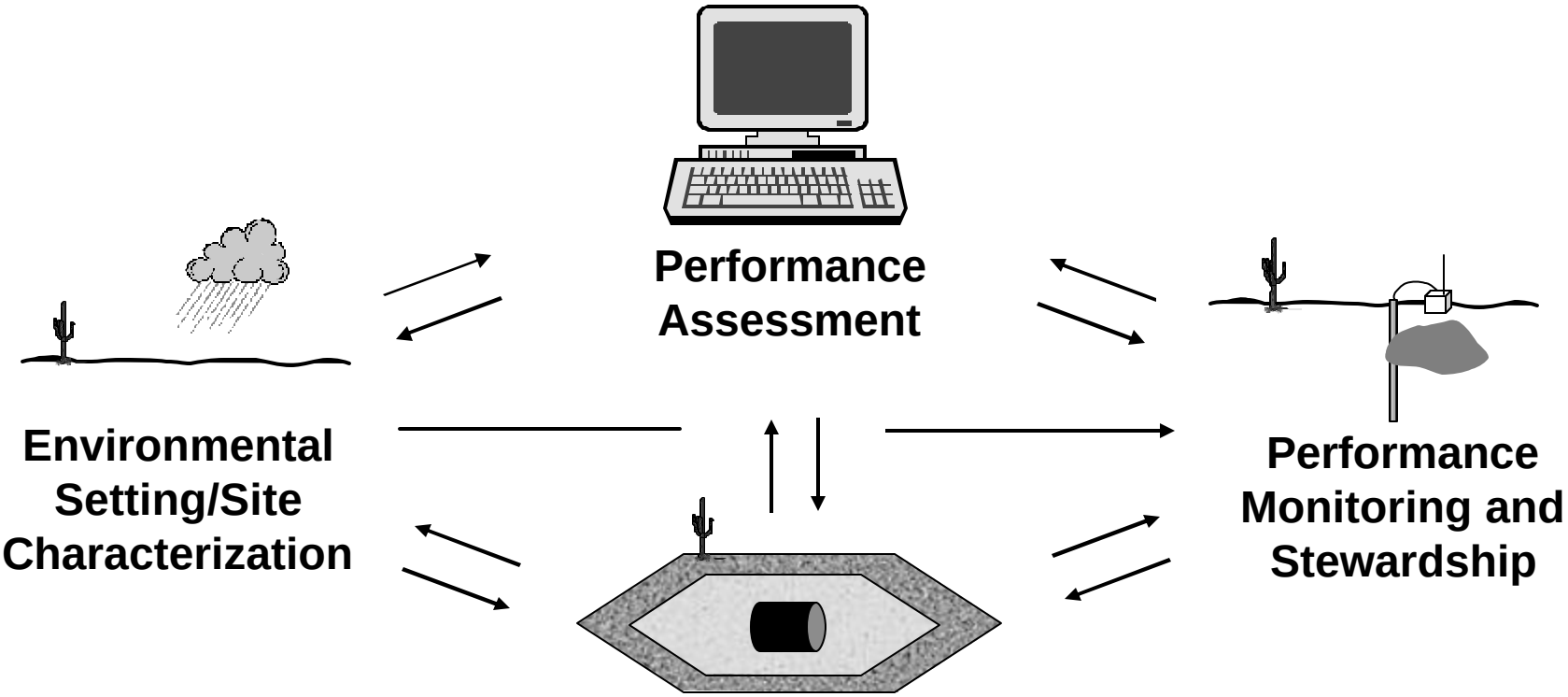
# Overview



- **Introduction**
- **Approach**
- **Demonstration**
- **Impact and Summary**

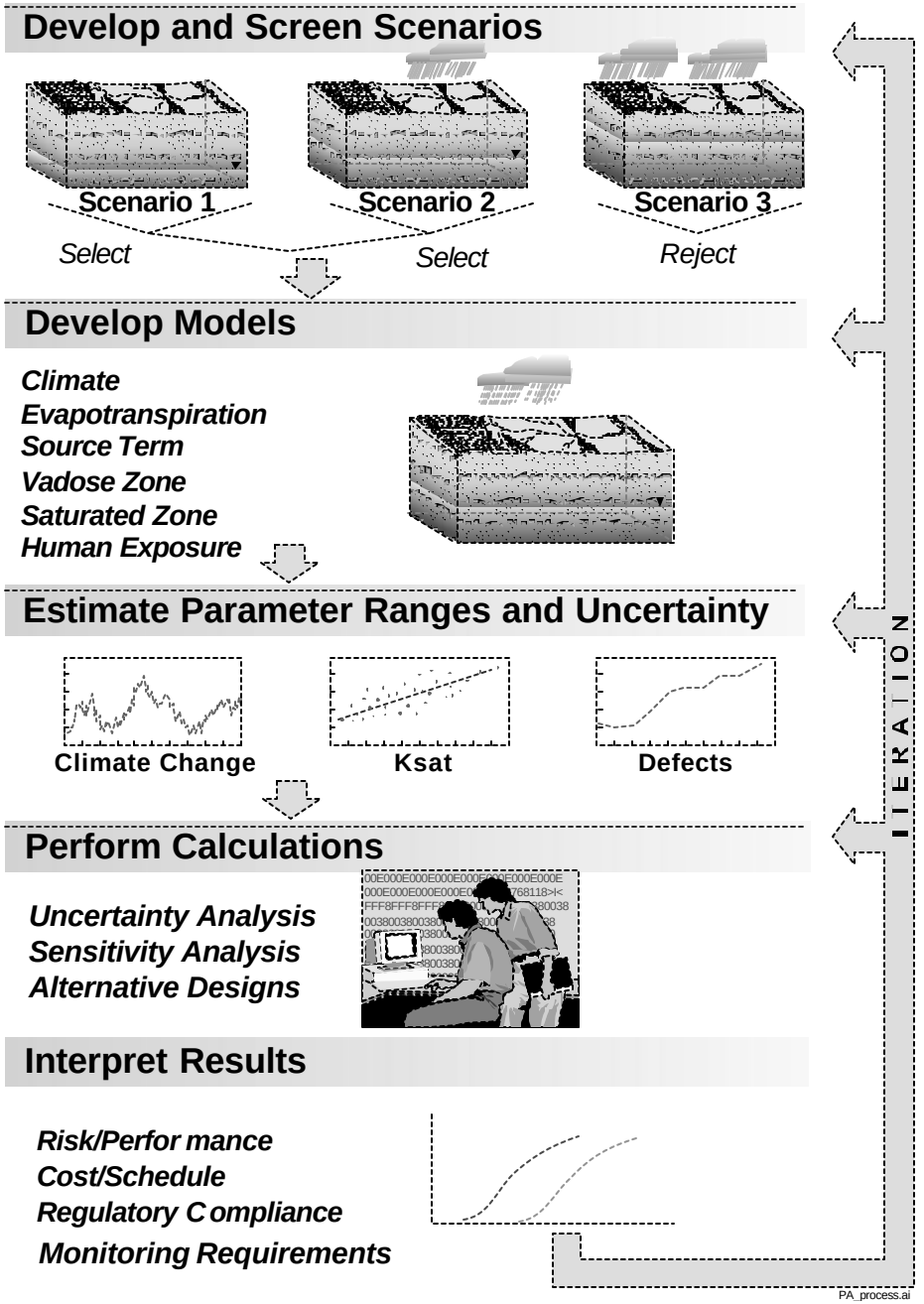
# Approach

**Public and Stakeholder Outreach**




**Regulatory Requirements**

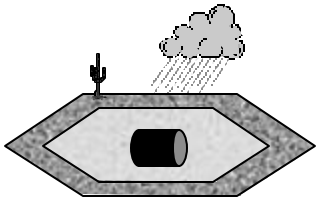
# Performance Assessment Process






Sandia National Laboratories

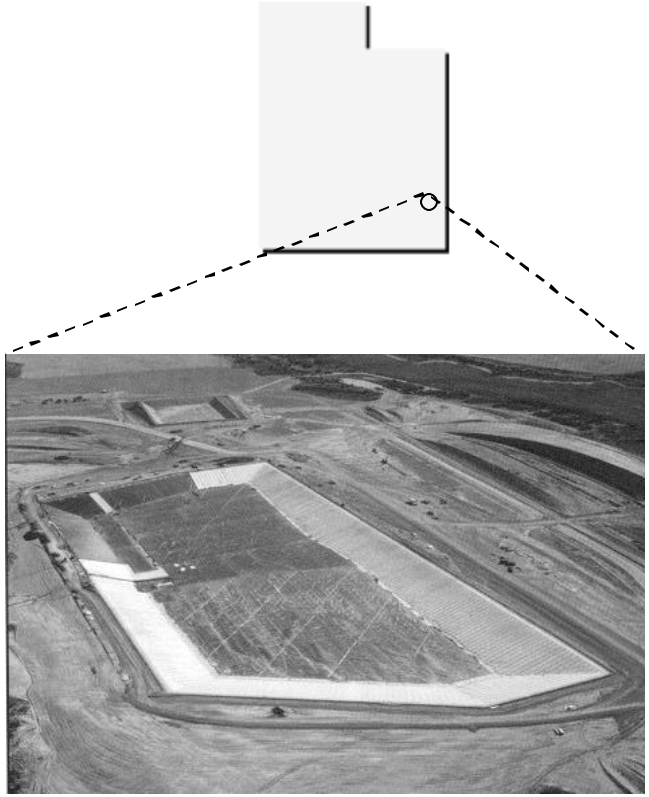
# Overview



- Introduction
- Approach
- Demonstration
- Impact and Summary

# Monticello Disposal Site

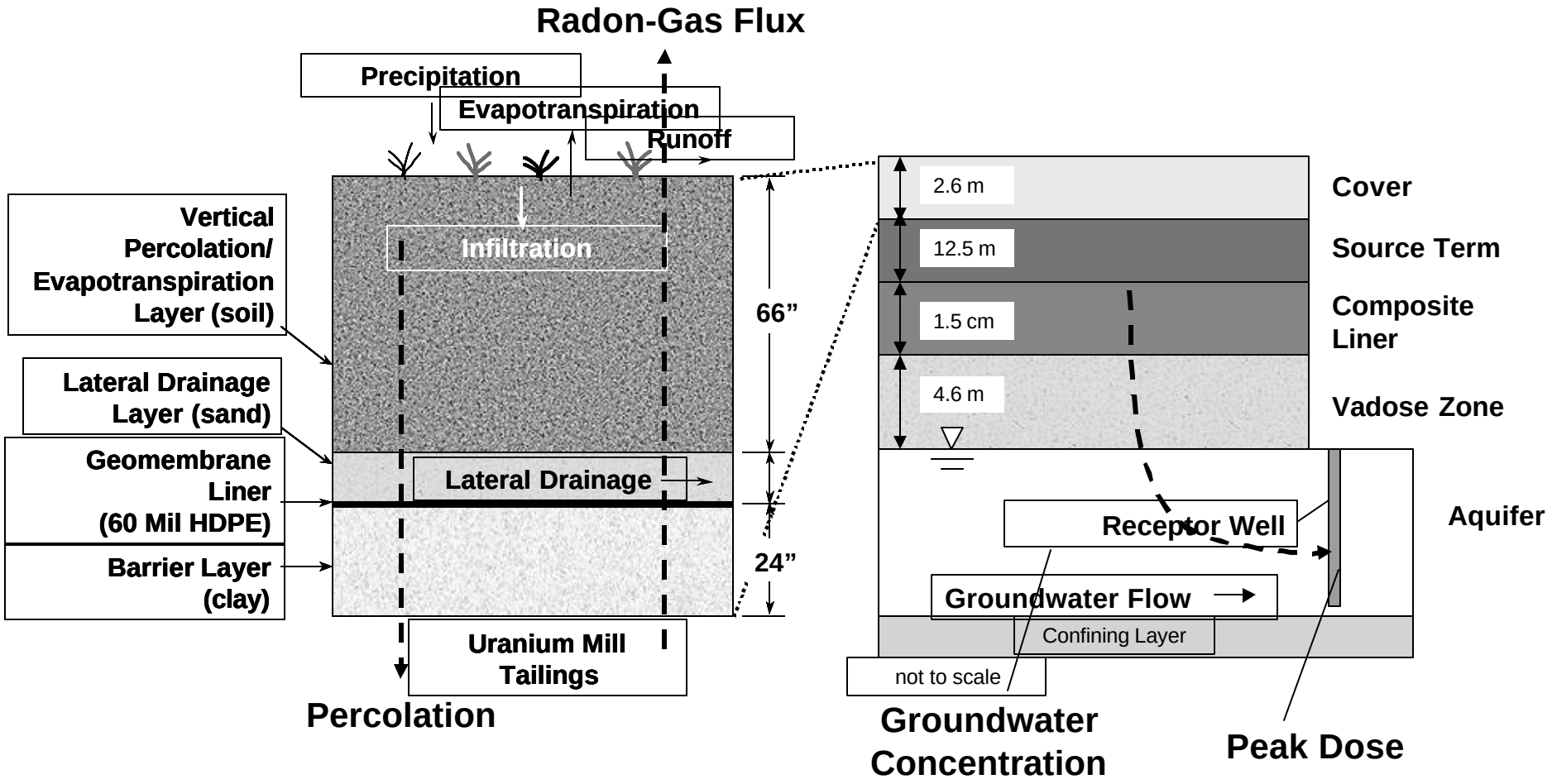
- **Permanent repository for 2.5 million cubic yards of low-level radioactive mill tailings and contaminated soils**
- **Sub-humid environment**
  - **Average annual temperature ~ 46 F**
  - **Average annual precipitation ~ 15 in**
- **Repository design consists of**
  - **composite cover system**
  - **double-liner system beneath tailings**
  - **leachate collection and removal system and leak-detection system**



# Conceptual Model Development

## Cover
(HELP, RAECOM codes)

## Total System
(FRAMES/MEPAS codes)





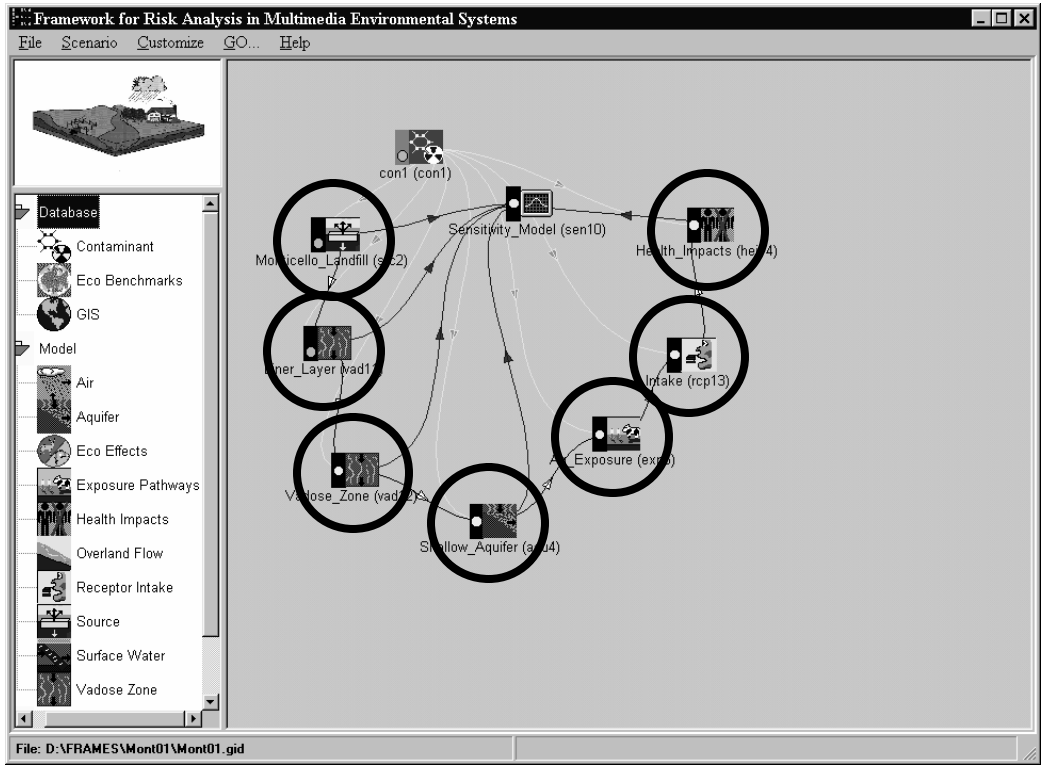

Sandia National Laboratories

# Integrated Performance-Assessment Model

- **Used FRAMES (PNNL) to integrate models for total-system performance assessment**
  - **Drag-and-drop software platform**
  - **Stochastic (Monte Carlo) analyses**

- **Source Term**
- **Vadose Zone**
- **Saturated Zone**
- **Human Exposure**
- **Radon-Gas Flux (RAECOM)**
- **Percolation (HELP)**

http://mepas.pnl.gov:2080/earth/earth.htm



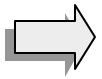



Sandia National Laboratories

# Performance-Assessment Analyses

## Examples from Monticello Study

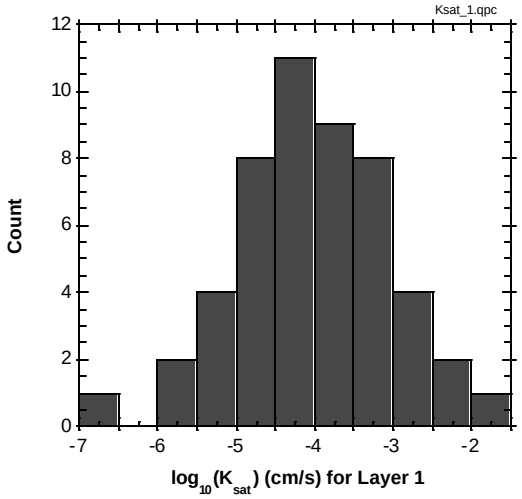
- **Risk/Uncertainty Analysis**
- **Sensitivity Analysis**
- **Alternative Design Comparison**

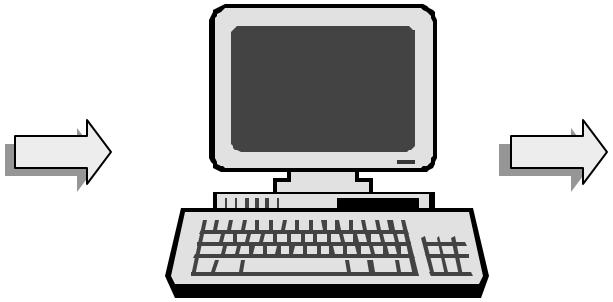


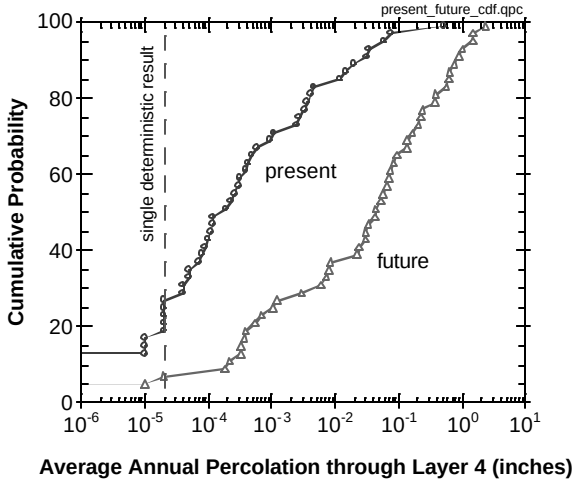
- **Meet regulatory performance metrics**
- **Identify important parameters**
- **Reduce costs**

# Risk/Uncertainty Analysis

- **Multiple computer "realizations" are simulated using stochastic inputs**
- **Ensemble of realizations yields probability distribution for "performance metric"**






Stochastic Inputs
(Latin Hypercube Sampling)

Multiple Computer Simulations
(HELP, FRAMES)

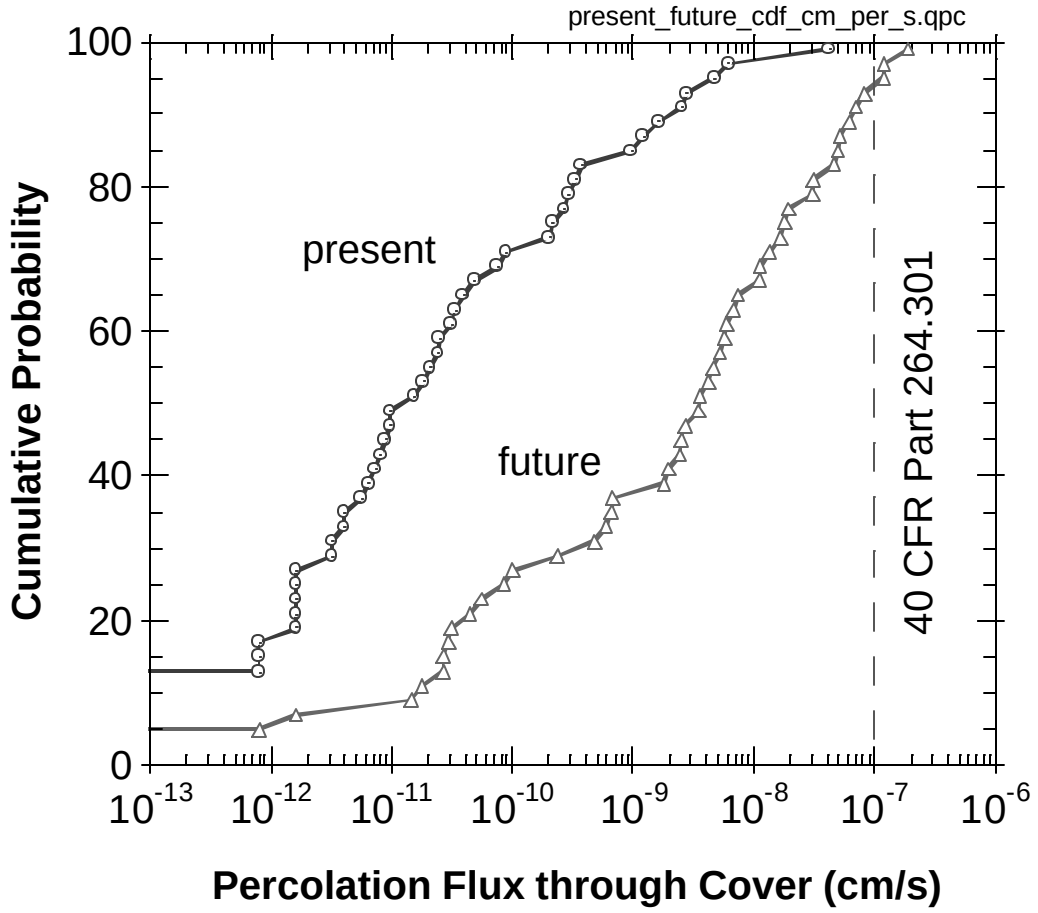
Distribution of Results
(Present and Future Conditions)



Sandia National Laboratories

# Uncertainty Analysis of Percolation through the Cover

- **95% of all simulated water percolation through cover are less than $10^{-7}$ cm/s**
- **Future conditions yield poorer performance**
  - **Increased defects in liner**
  - **Cooler, wetter climate**

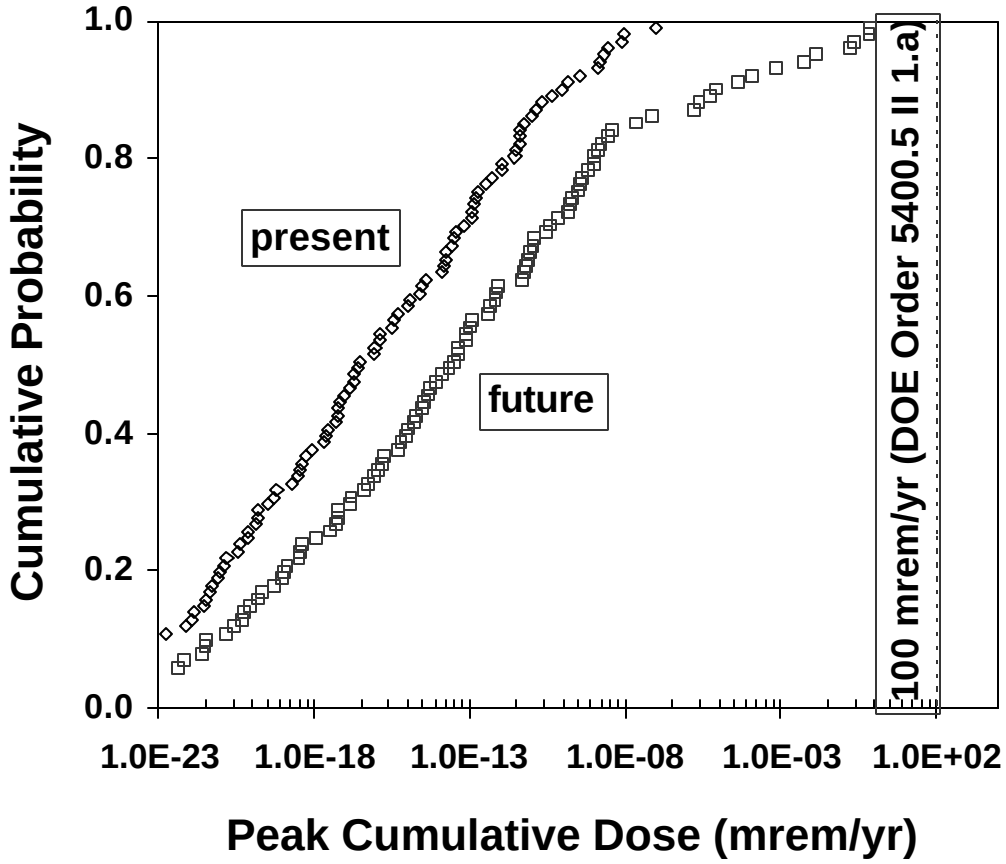




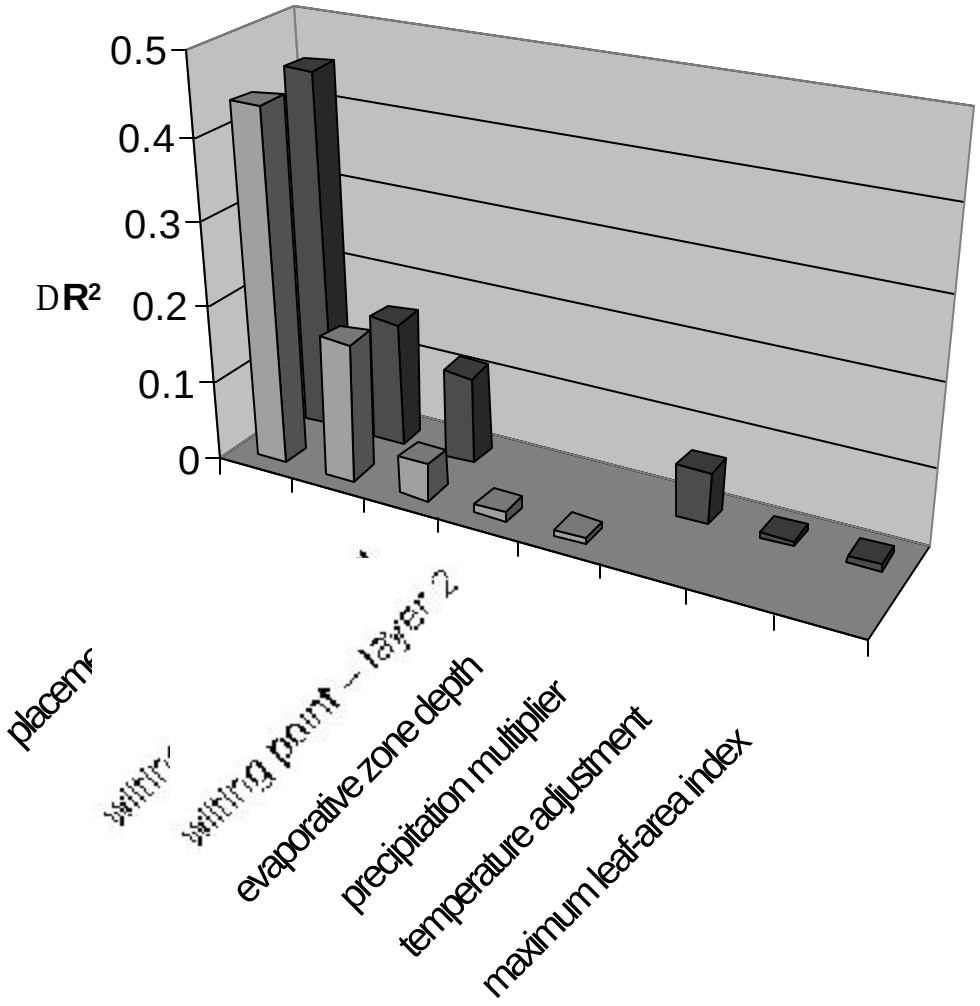

Sandia National Laboratories

# Uncertainty Analysis of Peak Dose

- **Uncertainties can be quantified**
- **Can use risk-based evaluation of performance**
- **Single deterministic result cannot quantify uncertainty or risk**



# Sensitivity Analysis




- **Sensitivity analysis can be used to identify parameters and processes most important to performance**
- **Stepwise linear-regression analysis quantifies relative importance of parameters**

**Sensitivity Analysis for Percolation through Cover**

- **Present Climate**
- **Future Climate**

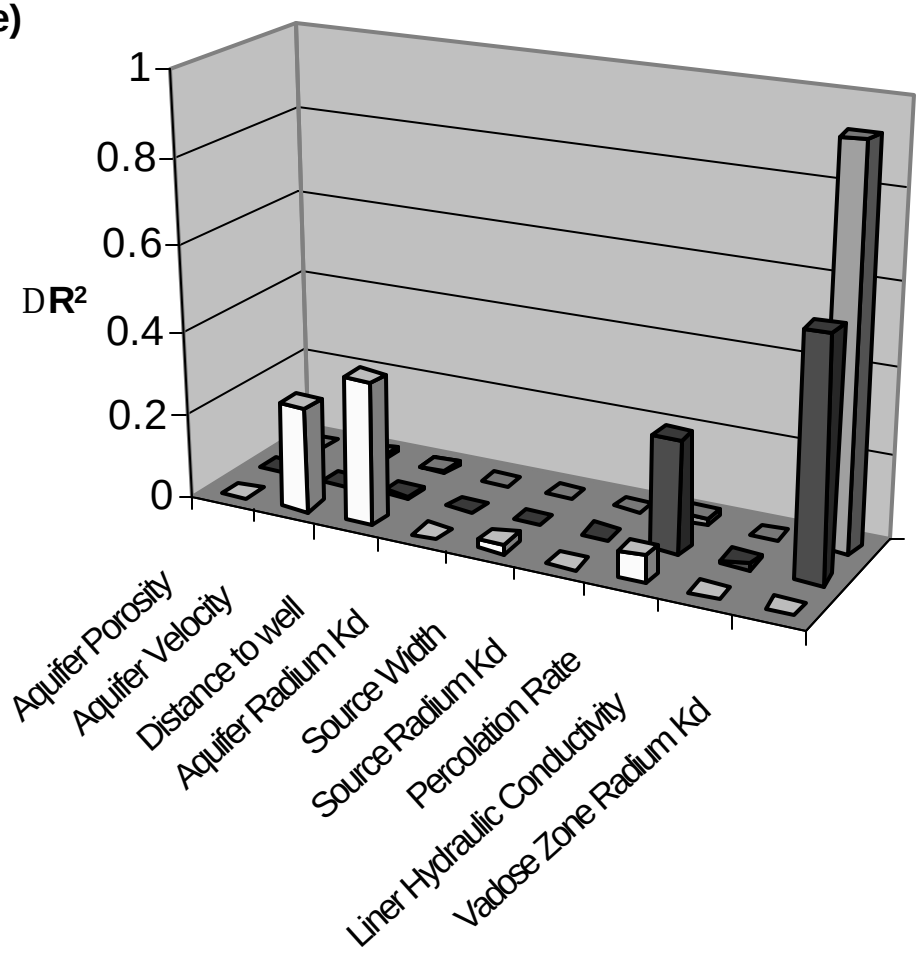


Sandia National Laboratories

# Sensitivity Analysis

**Sensitivity Analysis for Peak Cumulative Dose**

- **Shallow Aquifer (present climate)**
- **Shallow Aquifer (future climate)**
- **Deep Aquifer (future climate)**

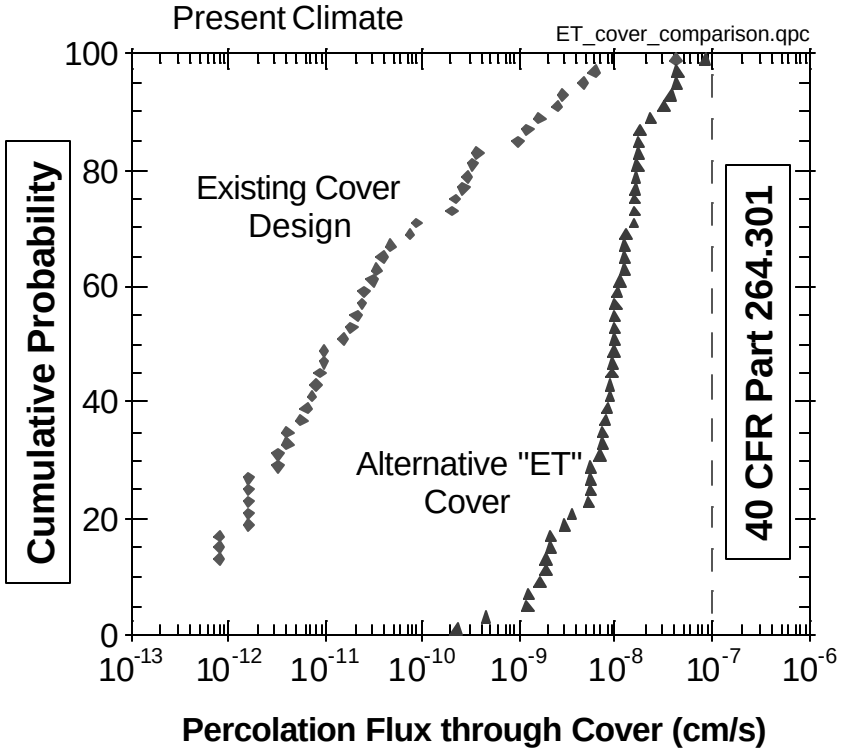


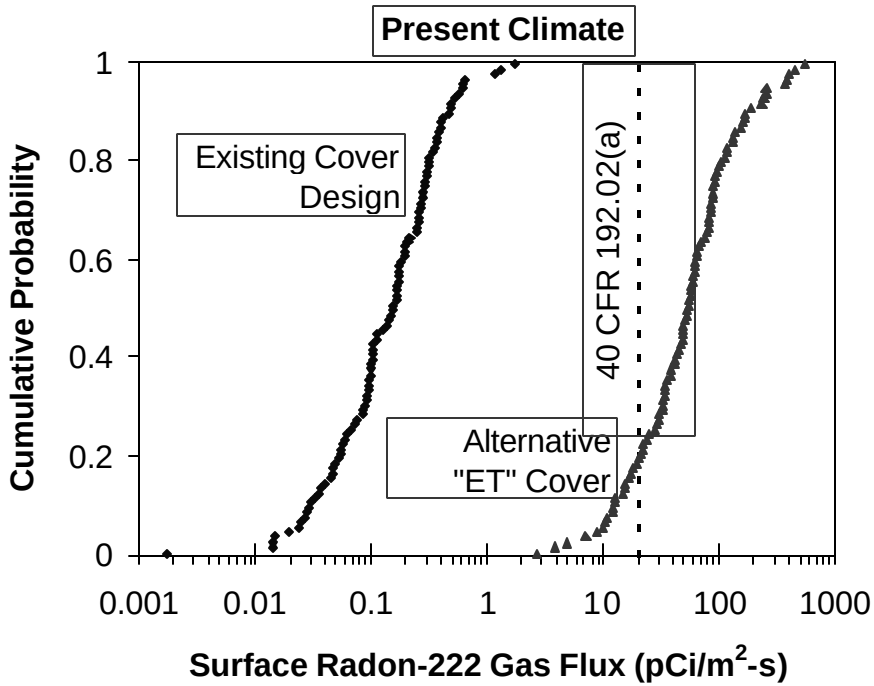



Sandia National Laboratories

# Alternative Design Comparison

- **Alternative designs can be compared using a probabilistic risk-based approach**
- **"ET" cover design performed adequately for percolation, but it greatly exceeded radon-gas-flux metric**

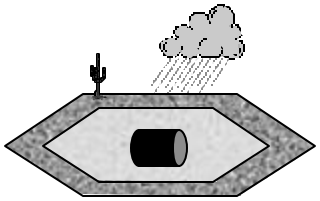





Sandia National Laboratories

# Overview

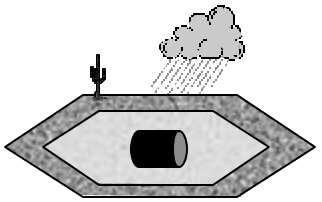


- **Introduction**
- **Approach**
- **Demonstration**
- **Impact and Summary**

# Impact and Summary

- **Probabilistic PA approach provides rigorous regulatory-based evaluation of long-term cover systems**
  - **Quantifies risk and uncertainty**

- **Sensitivity analyses identify processes and parameters most important to performance**
  - **Site characterization**
  - **Performance verification and monitoring**



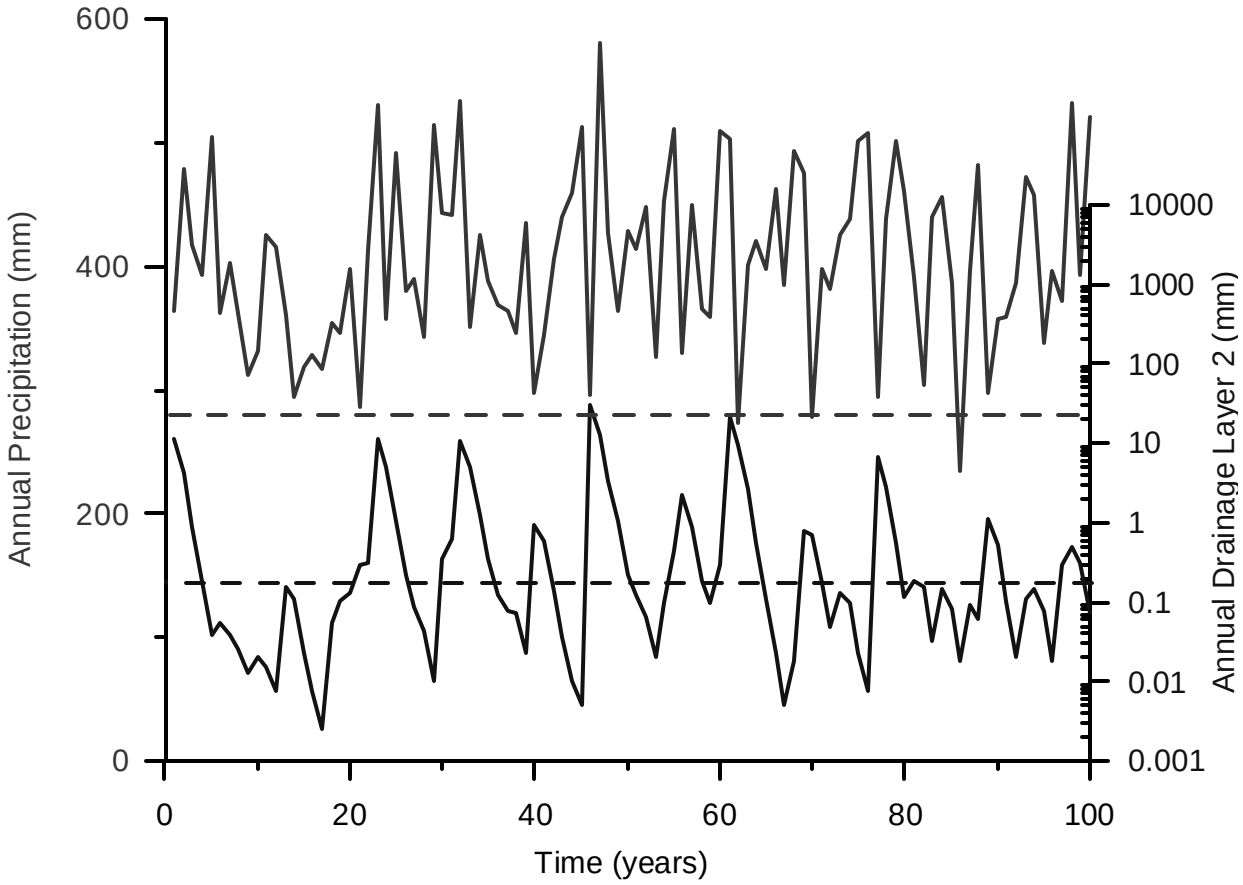
- **Provides risk-based comparison between alternative approaches and designs**
  - **Reduce costs and meet schedule**
  - **Meet regulatory performance metrics**

- **Software and methods are ready for use**
  - **www.sandia.gov/eesector/gs/gh/SAND2001-3032.pdf**

# Backup Slides

# Monticello Validation

HELP Simulation Results, Monticello Landfill Cover,
Expected-Value Run






Sandia National Laboratories

# Uncertainty Distributions for Input Parameters

- **Future Climate Conditions**
  - **Precipitation**
  - **Temperature**
- **Percolation through Cover**
  - **Evapotranspiration**
  - **Hydrologic Properties**
  - **Geomembrane Quality**
- **Transport Parameters**
  - **Sorption Coefficient**
  - **Dispersivity**
  - **Distance to Well**
- **Radon-Gas Flux Parameters**
  - **Diffusion Coefficient**
  - **Moisture Content**